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Optimization Strategy for Electric Vehicle Charging Station Development at Gas Stations Using GIS-AHP-SAW Framework

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Abstract

The rapid adoption of electric vehicles (EVs) requires the acceleration of electric vehicle charging station (EVCS) development. However, selecting optimal locations for EVCS development remains challenging. The EVCS Infrastructure Standard emphasizes that technical factors are essential, which aligns with earlier studies that point out the need to consider technical requirements along with sustainability criteria. This study aims to identify a novel optimization strategy for the EVCS development at gas stations, utilizing both technical and sustainability factors. We identified the gas station as an alternative site, conforming to regulatory guidelines and prior studies. This Framework integrates GIS, AHP, and SAW methods to achieve the research objectives. We evaluated the framework using suitability analysis, mathematical optimization techniques and conducted empirical study in a designated region of Indonesia to assess the practical applicability. The study's revealed substantial findings and efficient optimization strategies. The power network subcriterion ranking as the most critical in the hierarchy of criteria. The GS05 and GS22 locations attain an optimal level across all optimization scenarios. The improved accessibility of power network facilities can augment the total alternative weight by 22.5% and improve the coverage demand from 6% to 47%. The results indicated the optimization strategy focused on improving electricity network facilities at the gas station is the best strategy for EVCS Development. This framework demonstrated a replicable model for decision support systems within the domain of spatial informatics and smart infrastructure planning, specifically spatial decision support systems for EV infrastructure planning, and offers valuable insights for investor decision-making.

Keywords : *Charging Station, Electric Vehicle, Gas Station, Infrastructure, Optimization*

1. INTRODUCTION

Electric vehicles (EVs) have emerged as a significant trend in society, driven by growing environmental consciousness that motivates individuals to lower carbon emissions, particularly within the transportation sector, by transitioning from fossil fuel vehicles to electric alternatives [1], [2], [3]. The obligations for reducing global emissions, such as the Nationally Determined Contribution (NDC), highlight the adoption of electric vehicles as a crucial measure for mitigating carbon footprints [4]. Policies focused on energy efficiency and renewable energy further promote the attainment of these targets [5].

The implementation of adoption policies has led to a significant rise in EV adoption. In Indonesia, this resulted in a remarkable 77% increase in the total number of electric vehicles, with electric cars itself experiencing an incredible 479% growth [6], [7]. Unfortunately, the growth in electric vehicle adoption is not accompanied by sufficient charging infrastructure [6], [8], [9]. Survey results indicate that 71.2% of electric vehicle users in Indonesia encounter challenges in accessing EV charging station locations [6]. Indeed, enhancing the supporting infrastructure, such as charging facilities, is crucial for the broad adoption of electric vehicles [9], [10], [11], [12]. In earlier investigations, individuals utilizing

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electric vehicles emphasized the importance of home charging because of the longer duration required for charging [13]. The exponential increase in electric vehicle mileage enabling long-distance travel has led to a heightened demand for electric vehicle charging stations, it is bolstered by advancements in fast charging technology, which significantly reduces charging times for electric vehicles, bringing them closer to the refueling times of traditional fossil fuel vehicles [14], [15], [16].

Unfortunately, efforts to accelerate the the development of EVCS faces significant challenges in determining the most effective sites, and the sustainability factors and the geographic area is essential for putting the recommendations into practice [6], [17], [18], [19]. Although gas station locations have advantages over other alternative locations, existing research only provides an overview of the feasibility of gas stations as alternative locations for EVCS development [20], [21], [22]. The research results did not come up with a way to choose the best place for gas stations in an area to build EVCS based on the facility's readiness area to meet the requirements set by the EVCS Standard policy. Therefore, any EVCS development is not feasible to implement either in terms of location or cost [17], [23], [24], [25]. In fact, if the gas station developed EVCS has adequate facility readiness, it can reduce investment costs and potential new revenue sources [26]. Therefore, it is important to analyze optimization strategies in EVCS development efforts at gas stations while ensuring its feasibility both from technical and sustainability factors.

This study aims to identify a new optimization strategy for the development of EVCS at gas stations, incorporating both technical and sustainability factors into account. This study introduces a novel combination of GIS-AHP-SAW integrated with optimization analysis to provide a comprehensive strategy for EVCS development at gas stations. The study provides a detailed look at an important technical factor that is necessary to accelerate the growth of EVCS [27]. This perspective aligns with the implementation of the policy concerning the key requirements that EVCS must fulfill [21], [22]. The sustainability aspect is connected to addressing the interests of EV users. The Spatial Multi-Criteria Analysis Framework uses GIS, AHP, and SAW methods to ensure that the strategy for choosing and improving options is effective and meets the research goals, which were verified using suitability analysis and mathematical optimization methods. An empirical study was conducted in a specific region of Indonesia to evaluate the practical applicability of the framework to visually illustrate how the results of this approach are applied in practice, utilizing the actual distribution data of gas station locations. This research may be useful in to establish a comprehensive approach for decision-making to select the optimal strategy regarding the development of EVCS at gas stations, considering regulatory factors and existing facilities to enhance efficiency in the process. This plays a crucial role in investor decision-making and boosts the efficiency of infrastructure investments.

2. METHOD

This research discusses how to get the right optimization strategy in developing EVCS at gas stations. The spatial multi-criteria analysis (SMCA) framework, compiled from a combination of GIS, AHP, and SAW, is expected to provide results for analyzing gas station locations to develop EVCS. While several studies have integrated GIS and MCDM, implementation of sustainability and technical perspective based on regulatory successes makes this framework unique. Additionally, the results from this framework show a visual representation of how suitable different areas are by perform the suitability analysis that improves how we see the results. By using a scenario to improve suitability, we will see how different optimization strategies affect gas stations, with mathematical analysis using Maximum Coverage Location Problem (MCLP) helping to calculate and show how much each strategy improves performance. The related studies and highlights the novelty of the framework displays in table 1.

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Table 1. Related Study of EVCS Selection with GIS Method

Studies	Combined Method	Perspective Factors			Alternative Location
		Sustainability	Technical	Regulation	
[12]	GIS & ILP	V			Gas Station
[17]	GIS, FAHP & TOPSIS	V			Density Map
[20]	GIS & POI		V		Density Map
[23]	GIS & MCDA	V			Car Park
[25]	GIS, BN-BWM & TOPSIS	V			Coordinate Map
[28]	GIS, FAHP & TOPSIS	V			Density Map
[29]	GIS, AHP & TOPSIS	V			Suitability Map
[30]	GIS & FAHP	V			Density Map
[31]	GIS & MCLP		V		Gas Station
[32]	GIS, TOPSIS, SWARA	V			Suitability Map
This Study	GIS, AHP & SAW	V	V	V	Gas Station Suitability Map

2.1. Research Framework

Spatial Multi-Criteria Analysis (SMCA) is a method that facilitates the comparison of alternatives or scenarios based on multiple criteria, which are often conflicting, to support informed decision-making using spatial data [33]. This approach allows for the analysis of alternatives through the integration and weighting of spatial criteria to meet overarching objectives. This study introduces a novel combination of GIS-AHP-SAW integrated with optimization analysis to provide a comprehensive strategy for EVCS development. It utilizes diverse spatial conditions to facilitate intricate decision-making by merging GIS spatial analysis capabilities with multi-criteria decision-making methods, thereby offering more thorough and insightful solutions across different domains [34]. In the SMCA method, GIS is used as a spatial data analysis tool, where the role of spatial data and analysis is crucial to achieving appropriate geographic results [18]. The AHP-SAW method gives more accurate results than AHP-TOPSIS and other methods in the ranking stages [35]. This is in line with the findings of similar comparative studies [36], [37]. All ranking methods is stable, and simpler methods can always be suggested to make things easier to understand, calculate, interpret, and search [36]. This method has been successfully used in many other research areas and can now be used for EVCS site selection [37], [38]. The Sensitivity analysis, which is backed up by suitability analysis and optimal analysis evaluations to help you reach your research goals. The research stages can be seen in Figure 1.

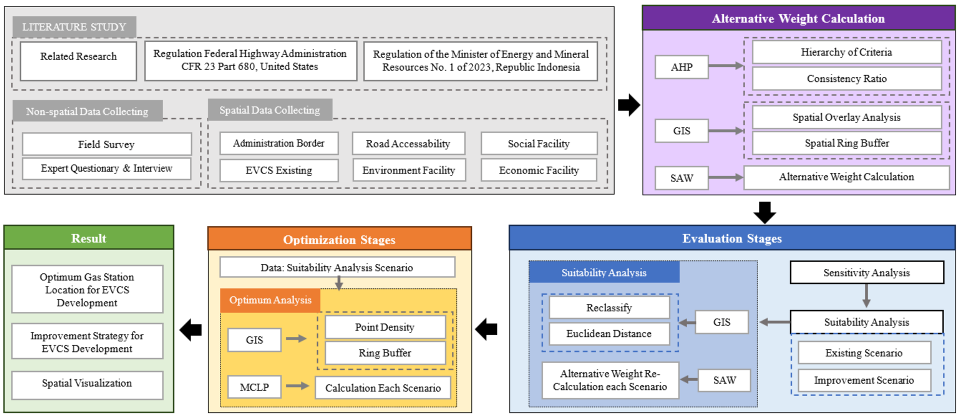

Figure 1. Research Stage

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2.2. Literature Study and Data Collection

At this stage, it is essential to gather supporting data derived from the literature studies phase, as illustrated in figure 1. The collection of this data will influence the parameters that constitute the hierarchy of criteria to be established in the subsequent phase. In line with the research goals and the factors that affect the results, we consider sustainability and technical aspects when setting the rules for collecting data, as shown in table 2. It's important to clearly define each criterion and the needs for geospatial data to gather spatial data with the right features for mapping and location analysis, which will help create data labels for each gas station as options.

Table 2 – Data Collection and Criteria

Criteria	Definition	Studies	Data Source	Data Label (5 Scale)
C.1.1 Social Facility	Proximity to social facilities to the gas station where the EVCS will be built.	[17], [28], [29], [32], [39], [40]	Google My Maps, PRBI	Density (1-5 Scale)
C.1.2 Economic Facility	Proximity to economic facilities to the gas station where the EVCS will be built.	[17], [28], [32], [39], [40], [41]	Google My Maps, PRBI	Density (1-5 Scale)
C.1.3 Environment Facility	Proximity of city park to gas stations where EVCS will be built.	[28], [29], [32], [39], [40], [41]	Google My Maps, PRBI	Density (1-5 Scale)
C.1.4 Road Accessibility	Type/width of road access to the location of the gas station where the EVCS will be built	[17], [28], [29], [41]	Google My Maps, PRBI (Road Type)	5= Toll & Alterial 3= Collector 1 = Local Road
C.2.1 Land Area	Availability of Land Area used for EVCS Charging Points at Gas Station	[21], [22]	availability of land area at Gas Station	5 = 4 Ports; 4 = 3 Ports; 3 = 2 Ports; 2 = 1 Port; 1 = 0 Port;
C.2.2 Power Network	Fulfillment of primary and backup power source specifications in accordance with the minimum requirement EVCS development at Gas Station	[21], [22]	Primary & Backup Power Source (88 kW) at Gas Station	5 = Both 100%; 4 = one achv. 100%; 3 = Both 50%; 2 = one achv. 50%; 1 = Both below 50%.
C.2.3 Manpower Availability	Availability of certified customer service personnel, certified security personnel and certified technicians at gas stations.	[21], [22]	Organization Structure of Gas Station	5 = 3 of 3 & Certf; 4 = 3 of 3 & One Certf; 3 = 3 of 3 & Non Certf; 2 = 2 of 3; 1 = 1 of 3.
C.2.4 Supporting Facility	Availability of public facilities at gas stations such as waiting rooms, toilets, places of worship, retail and restaurants/cafes.	[21], [22]	Supporting Facility of Gas Station	1 point / Type of Facility Maximum 5 point.

2.3. Alternative Weight Calculation

This phase entails a thorough examination of the criteria utilized. The AHP functions as a structured method for creating a priority scale within a hierarchical set of criteria that impacts research goals. The AHP method is grounded in four essential principles: decomposition, comparative judgment, synthesis of priorities, and comparative judgment [42]. This study employs the AHP method to

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determine appropriate weight values for each criterion, incorporating insights from an EV development expert and utilizing a pairwise comparison scale grounded in Saaty's nine relative scores. Employ the square root method to examine the eigenvectors of the matrix that was constructed earlier and express the eigenvalues [43], The subsequent step involves verification using the consistency index (CI). Should the CR be less than or equal to 0.1, the consistency is deemed satisfactory; however, if it surpasses this threshold, expert intervention for data retrieval is necessary, as analyzed in (1) and (2). The criteria influencing have been compiled based on regulations associated with EVCS infrastructure standards [21], [22]. The criteria are outlined in table 2.

$$\mathrm{CI} = \frac{\lambda_{max}{}^{-n}}{n-1} \quad (1)$$

$$\mathrm{CR} = \frac{CI}{RI} \quad (2)$$

The goal at this stage is to obtain the importance weights between criteria, alternative weights and rankings, GIS is used to evaluate the distribution of spatial data from data collection in the previous stage, ArcGIS application is used with spatial overlay commands and ring buffer analysis so that spatial performance data is obtained on each alternative. The Simple Additive Weighting (SAW) will analyze the results of criteria weighting and performance score data for each alternative. In this research, attribute is a benefit where the largest value is the best. The advantage is that it can complete rankings with complex criteria. The normalization formula and the ranking evaluation formula as analyzed in (3) and (4).

$$R_{ij} = \left\{ \frac{Xij}{Max^{x}ij} \right\} \text{if j} = \text{Benefit} \quad (3)$$

$$V_i = \sum_{j=1}^{n} w_j \, R_{ij} \quad (4)$$

2.4. Sensitivity Analysis

At this stage, we will conduct sensitivity analysis on the outcomes of the alternative weighting and ranking phases. To ensure that the method used is the best, sensitivity analysis is used to determine the robustness of the decision-making process to changes in criteria weights and their impact on the resulting alternative ranking [44]. This analysis will compare ten scenarios involving changes in criteria weights:

- Scenario A: All Sub-Criteria Weighted based on AHP.
- Scenario B: All Sub-Criteria Weighted Equally.
- Scenario C: Weight of C.1.1 increased 50%, other sub-criteria decreased equally.
- Scenario D: Weight of C.1.2 increased 50%, other sub-criteria decreased equally.
- Scenario E: Weight of C.1.3 increased 50%, other sub-criteria decreased equally.
- Scenario F: Weight of C.1.4 increased 50%, other sub-criteria decreased equally.
- Scenario G: Weight of C.2.1 increased 50%, other sub-criteria decreased equally.
- Scenario H: Weight of C.2.2 increased 50%, other sub-criteria decreased equally.
- Scenario I: Weight of C.2.3 increased 50%, other sub-criteria decreased equally.
- Scenario J: Weight of C.2.4 increased 50%, other sub-criteria decreased equally.

2.5. GIS-based Suitability Analysis

The alternative weight derived from AHP stages facilitates GIS suitability analysis, which is employed to visualize the appropriateness of EVCS locations in relation to their proximity to users or defined criteria [41]. In spatial analysis, alternative priority weights are classified into six separate categories: very unsuitable (VU), unsuitable (U), slightly unsuitable (SU), slightly suitable (SS), suitable (S), and very suitable (VS) [17]. The GIS suitability analysis delineates the essential requirements for the implementation of the process: Begin by evaluating the significance of gas stations in the spatial data. Next, organize the various alternative weight values into six separate categories with reclassify command. Finally, using euclidean distance analysis to generate the suitability map.

The criteria for improvement to identify the suitable development strategy for achieving the anticipated standardization are examined through the following scenarios. Data will be evaluated against five improvement scenarios by simulating the complete attainment of each criterion to discern the impact of infrastructure standards on the suitability of locations. For this reason, the scenario is focused on criterion C.2 where it is still possible to make improvements by simulating the achievement of each sub-criterion as follows:

- Scenario 1: Based on AHP+SAW Result
- Scenario 2: Score alternative of C.2.1 is max
- Scenario 3: Score alternative of C.2.2 is max
- Scenario 4: Score alternative of C.2.3 is max
- Scenario 5: Score alternative of C.2.4 is max

2.6. Optimization Analysis

We formulate the facility location problem with the target of maximizing the destination point that electric vehicle users want to reach with the same number of gas stations with the most suitable facilities that will be developed EVCS. This is obtained by determining the MCLP at gas stations with a radius of 5 km [31]. GIS was used for optimal analysis under two test conditions. To determine the most stable site for EVCS development, the gas station location must first meet extremely appropriate requirements for every scenario. The second condition test determines the best coverage for each scenario by conducting a suitable analysis of the data with highly appropriate gas stations in each suitability scenario. Using five scenarios from suitability analysis, buffer, erase, and overlay analysis commands were used to perform GIS analysis with ArcGIS. which can be expressed as:

$$\text{Maximize } Z = \sum_{i=1}^{n} a_i \tag{5}$$

$$s.t\ a_i \leq \sum_{j=1}^{m} C_{\{d_{ij} \leq r\}} \cdot x_j \quad \forall i = 1, 2, \dots n \tag{6}$$

$$\sum_{j=1}^{m} x_j = x \tag{7}$$

$$\mathrm{xj} \in \{0,1\}\ \forall \mathrm{j} = 1, 2, \dots, \mathrm{m} \tag{8}$$

$$\mathrm{a_i} \in \{0,1\}\ \forall_{\mathrm{j}} = 1, 2, \dots, \mathrm{n} \tag{9}$$

The objective function *Z* to be achieved in (5) aims to determine the maximum number of user-POI that can be effectively served by potential gas stations *x*, which meet the suitability criteria for EVCS development as specified in (7) and is computed using (6). In this context, *n* denotes the total count of User-POI, indicated by *i*, where *ai* is defined as binary according (9) Specifically, *ai* =1 if *i* meets the criteria outlined in (6). Formula (6) stablishes that the distance from *i* to *j*, denoted as *dij*, is maintained at a radius *r*, with the center point *r* being a Priority Gas Station, or represented by *xj*. Here, *xj* is defined as binary according to formula (8) where *xj* =1 if *j* is a potential gas station and *xj*=0 otherwise. Should the condition in (8) is achieved, then *ai* = 1, indicating that entity i falls within the scope of Z.

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3. RESULT

3.1. Study Area

The study examines the retail gas station network located in the Banyumas Residence. A total of 63 alternative gas station locations, labeled from GS01 to GS63, are strategically distributed across the region. The study utilizes spatial data that spans latitudes from -7.0300°S to -7.666°S and longitudes from 108.040°E to 109.447°E. The Banyumas Residence chosen for analysis is a prefecture in Central Java, Indonesia, with a population of around 3.3 million inhabitants, which collectively has the second-highest vehicle count [45]. This context offers potential for EV advancement, yet it currently lacks a substantial EV facility to foster the development of the EV ecosystem.

3.2. Data Collections

At this stage, observation data from gas stations and spatial data have been obtained to support the analysis, including the boundaries of the study area, alternative points of gas stations, and the distribution of user destination points as parameter points for sustainability facilities according to the point of interest (POI) of EV users. We obtained the data using the sources and methods outlined in table 2. Figure 2 visualizes the results of data distribution.

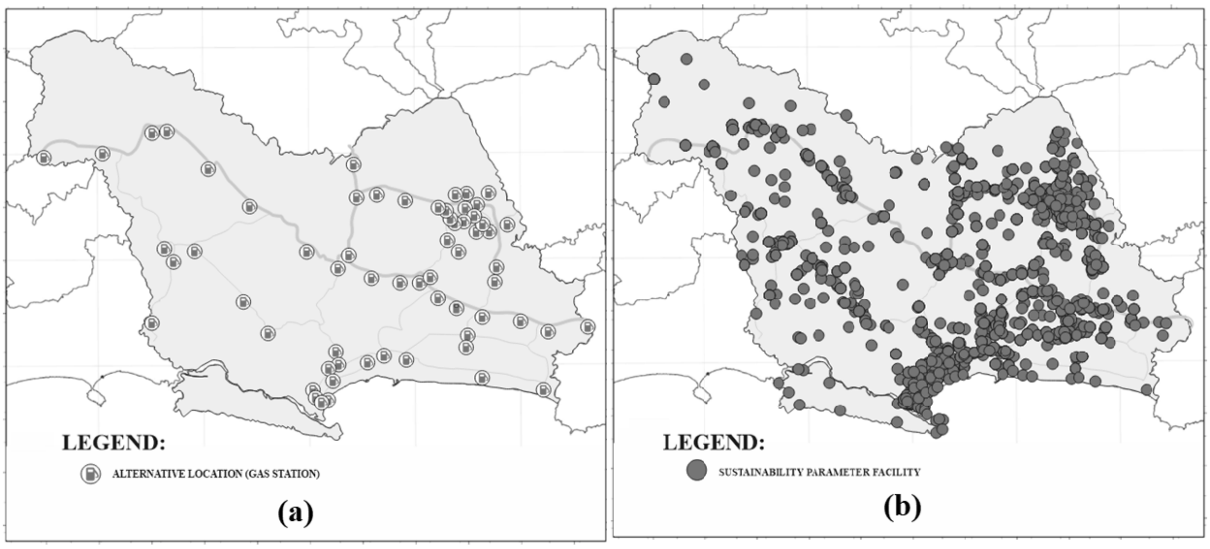

Figure 2. Distribution of (a) alternative location and (b) sustainability parameter facility

The Figure 2, indicates that there are 63 gas stations scattered according to sub-figure (a) within the study area; besides that, 1,201 POI data were also obtained as sustainability parameter facilities consisting of economic, social, and environmental facilities in the study area, which can be seen in sub-figure (b). This data will support the processing of alternative performance in the next stage. Spatial data was obtained and analyzed using ArcGIS Pro 3.4 Application with computer specifications of 11th Gen Intel® Core™ i5-11400H @ 2.70 GHz, Windows 11 Home 64-bit (10.0, Build 26100), and 16GB DDR4 RAM.

3.3. Alternative Weight Calculation Stages

3.3.1. Hierarchy of Criteria AHP

Data from table 2 indicates that we have now examined the critical elements required to determine the location of EVCS. As illustrated in figure 3, the implementation of an approach that takes

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sustainability and technical factors into account generated various types of criteria that impact the selection of the most suitable site for gas stations for EVCS development.

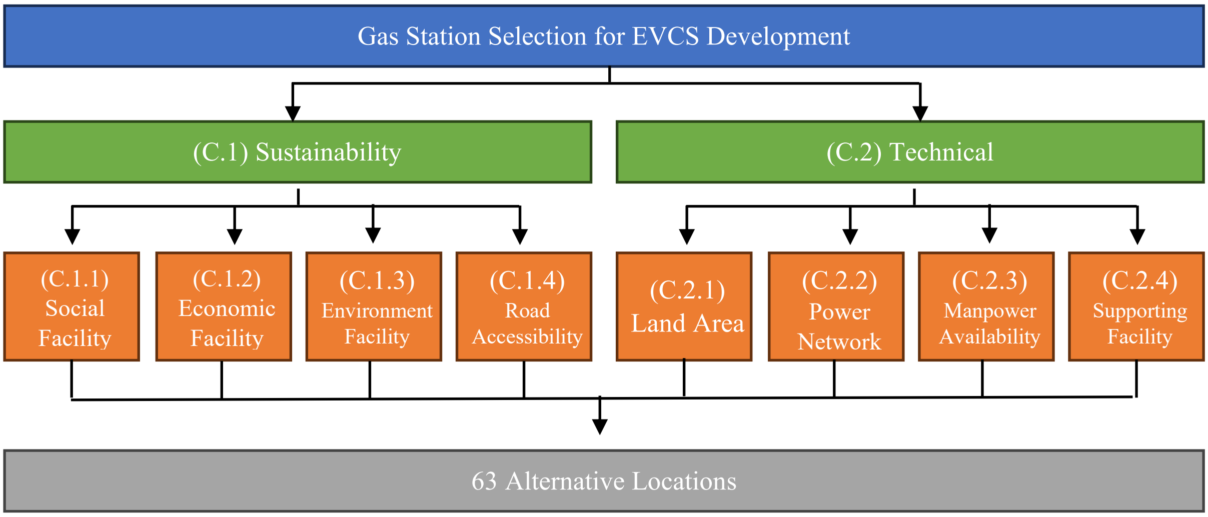

Figure 3. Hierarchy of Criteria

As shown in figure 3, there are 63 alternatives that will be analyzed according to sustainability (C.1) and technical (C.2) criteria, where each C.1 criterion consists of sub-criteria for the proximity of social facilities (C.1.1), economic facilities (C.1.2), environmental facilities (C.1.3), and ease of road accessibility (C.1.4). For criteria C.2, it is influenced by the availability of land area for charging port development (C.2.1), power network (C.2.2), manpower availability (C.2.3), and supporting facilities (C.2.4) available at the gas station. This stage supports the criteria that will be analyzed at the stage of weighting criteria and ranking alternative weights.

3.3.2. Weighting of Criteria

Next step, experts from EV ecosystems, gas station managers, leaders of the EV community, and national energy regulatory officers who know a lot about the energy sector and the EV community filled out a comparison questionnaire based on the criteria shown in figure 2. At this stage, it was confirmed that the CR data from each expert was consistent and had been verified using the super decision application. The information collected from all experts was combined using the geometric mean. At this stage, pairwise comparison analysis and normalization will be carried out as shown in table 3, table 4 and table 5 which was analyzed using formulas (1) and (2).

Table 3 – Pairwise Comparison & Normalization Matrix Sub-Criteria C.1

Pairwise Comparison Matrix					Normalization Matrix							
Criteria	C.1.1	C.1.2	C.1.3	C.1.4	Criteria	C.1.1	C.1.2	C.1.3	C.1.4	P-Vector	Weight	Eigen
C.1.1	1.000	0.302	0.795	0.180	C.1.1	0.090	0.113	0.109	0.064	0.375	0.0941	1.048
C.1.2	3.310	1.000	4.229	0.880	C.1.2	0.298	0.374	0.578	0.311	1.560	0.3935	1.052
C.1.3	1.257	0.236	1.000	0.773	C.1.3	0.113	0.088	0.137	0.273	0.611	0.1517	1.110
C.1.4	5.566	1.136	1.294	1.000	C.1.4	0.499	0.425	0.177	0.353	1.454	0.3608	1.022
SUM	1.000	0.302	0.795	0.180	SUM	1.000	1.000	1.000	1.000	4.000	1.0000	4.232

The results of table 3 indicate the results of the expert judgment of the weight of sub-criteria C.1 which is analyzed with formulas (1) and (2). From the calculation results, the CR value = 0.0869 or $\leq$ 0.1 which means that the results are consistent.

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Table 4 – Pairwise Comparison & Normalization Matrix Sub-Criteria C.2

Pairwise Comparison Matrix					Normalization Matrix							
Criteria	C.2.1	C.2.2	C.2.3	C.2.4	Criteria	C.2.1	C.2.2	C.2.3	C.2.4	P-Vector	Weight	Eigen
C.2.1	1.000	0.253	5.091	1.470	C.2.1	0.172	0.158	0.305	0.199	0.834	0.2049	1.195
C.2.2	3.956	1.000	7.969	4.527	C.2.2	0.678	0.625	0.477	0.614	2.394	0.6048	0.968
C.2.3	0.196	0.125	1.000	0.376	C.2.3	0.034	0.079	0.060	0.051	0.223	0.0545	0.911
C.2.4	0.680	0.221	2.659	1.000	C.2.4	0.117	0.138	0.158	0.136	0.549	0.1356	1.000
SUM	5.833	1.599	16.719	7.373	SUM	1.000	1.000	1.000	1.000	4.000	1.0000	4.074

The results of table 4 indicate the results of the expert judgment of the weight of sub-criteria C.2 which is analyzed with formulas (1) and (2). From the calculation results, the CR value = 0.0274 or ≤ 0.1 which means that the results are consistent.

Table 5 – Pairwise Comparison & Normalization Matrix Criteria

Pairwise Comparison matrix			Normalization Matrix					
Criteria	C.1	C.2	Criteria	C.1	C.2	P-Vector	Weight	Eigen
C.1	1.000	0.874	C.1	0.466	0.466	0.933	0.46638	1
C.2	1.144	1.000	C.2	0.534	0.534	1.067	0.53362	1
SUM	2.144	1.874	SUM	1.000	1.000	2.000	1.00000	2

The results of table 5 indicate the results of the expert judgment of the weight of Criteria C.1 and C.2 which is analyzed with formulas (1) and (2). From the calculation results, the CR value = 0 or ≤ 0.1 which means that the results are consistent. At this stage, all criteria and sub-criteria have been analyzed with criteria weight values as shown in table 6.

Table 6 – Criteria Weight Value

Criteria	C.1	C.2	C.1.1	C.1.2	C.1.3	C.1.4	C.2.1	C.2.2	C.2.3	C.2.4
Weight Value	0.466	0.533	0.044	0.183	0.071	0.168	0.109	0.323	0.029	0.072

The results of table 6 indicated that the technical criteria (C.2) are slightly more important than sustainability criteria (C.1), with weights of 0.46638 for C.1 and 0.53362 for C.2. The hierarchy of importance among the sub-criteria is as follows: power network (C.2.2), economic facility (C.1.2), and road accessibility (C.1.4), The analysis of the data acquisition results indicates that the overall outcome is CR ≤ 0.1, signifying that the consistency aligns with the established requirements.

3.4. Weighting and Ranking of Alternative Location

The criteria weight data obtained according to Table 6, will be analyzed using SAW with performance data according to Table 2 and the results of data collection. Spatial data from criterion C.1, consisting of C.1.1, C.1.2, C.1.3, and C.1.4, requires user-POI distribution data by assessing the presence of facilities around the maximum travel distance from the EVCS location, which is at a radius of 500 meters; the results are obtained according to table 2, the point density command and ring buffer command in ArcGIS application were used to obtain the performance of each alternative.

Criterion C.2 evaluates the performance of criteria C.2.1, C.2.2, C.2.3, and C.2.4 in relation to the regulations listed in table 2, the performance of each alternative is assessed by direct observation of the facilities available at the gas station.The results of data collection are shown in figure 4.

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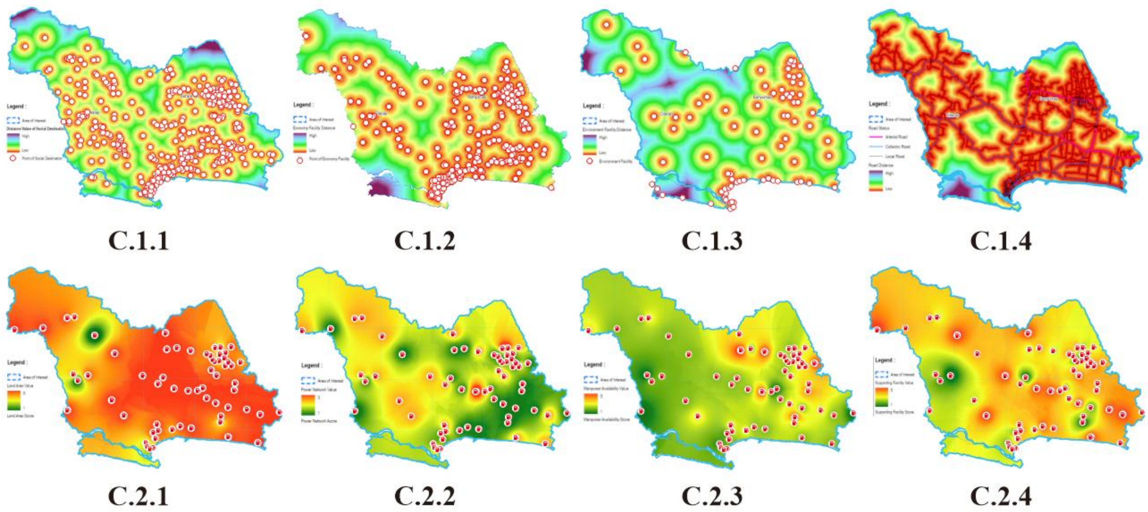

Figure 4. Criteria Data Collection

Visualization of each subcriteria according to Figure 4 indicates the unequal distribution of performance between alternatives, from these results ranking is carried out using the SAW method with formulas (3) and (4). Sample data of best ten alternative weights can be seen in table 7.

Table 7 – Best Ten Alternative Weight

	Rank of Alternatives									
	1	2	3	4	5	6	7	8	9	10
Alternative	GS22	GS05	GS37	GS29	GS30	GS30	GS39	GS02	GS18	GS56
Weight of Alt.	0.6698	0.6659	0.5814	0.5813	0.5756	0.5651	0.5630	0.5592	0.5563	0.5563

After calculating the ranking with the SAW method as table 7, the results show that alternative GS22 is the location with the highest achievement of 0.6698, followed by GS05 with 0.6659, and the lowest achievement is GS54 with a value of 0.2950. The upper limit is 0.6698, the lower limit is 0.2950, and the average alternative weight is 0.47793.

3.5. Sensitivity Analysis

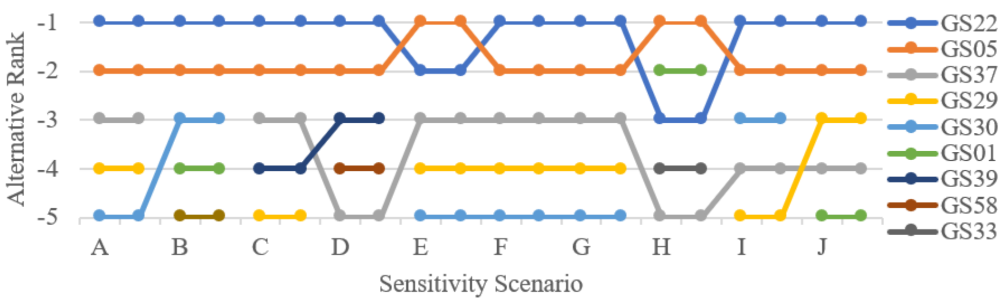

Figure 5. Alternative Ranking Changes from Sensitivity Scenario

This research performs sensitivity analysis based on the outcomes of the AHP and SAW phases. Analysis is used according to the scenario determined in the sensitivity method to determine the stability of the ranking results. The sensitivity results revealed an overall sensitivity of 98.7%. To see how stable the analysis results are, figure 5 shows how the ranking changes in all sensitivity scenarios, this analysis will compare ten scenarios involving changes in criteria weights.

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The figure 5 indicate that the ranking results with the combination of GIS, AHP, and SAW methods have a high stability with 80% of the 10 sensitivity scenarios. In scenario A, all subcriteria are weighted based on AHP. In scenario B, we weight all sub-criteria equally. In scenarios C to J, the weight of subcriteria increased 50% separately, and other subcriteria decreased equally.

3.6. Suitability Analysis Scenario

Based on the results of the AHP-SAW analysis, the suitability analysis stage is carried out with the improvement scenarios that have been determined in the method. At this stage, the scenario is based on potential improvements that may be made to achieve the most optimal conditions to meet applicable regulations. For this reason, the scenario is focused on criterion C.2, where it is still possible to make improvements by simulating the achievement of each sub-criterion, namely land area, power network, manpower availability, and supporting facilities.

The first step is to collect data on the distribution of alternative points as Figure 2 (a), the next step, based on the results of alternative weighting in table 7, a natural break is carried out using the GIS reclassify command according to 6 levels of classification as the data weight range table 8. The final stage is to recalculate the alternative weights using the SAW method for all scenarios where the performance results of each scenario have been presented in table 8.

Table 8 – Performance of Suitability Analysis Scenario

Data	Weight Range	Suitability of Alternative Location in Each Scenario				
		1	2	3	4	5
Very Unsuitable	0,2950 - 0,3575	4	3	-	3	1
Unsuitable	0,3575 - 0,4200	8	7	-	8	4
Slightly Unsuitable	0,4200 - 0,4824	21	17	-	15	18
Slightly Suitable	0,4824 - 0,5449	18	21	-	21	26
Suitable	0,5449 - 0,6073	10	13	4	14	12
Very Suitable	0,6073 - 0,6698	2	2	59	2	2

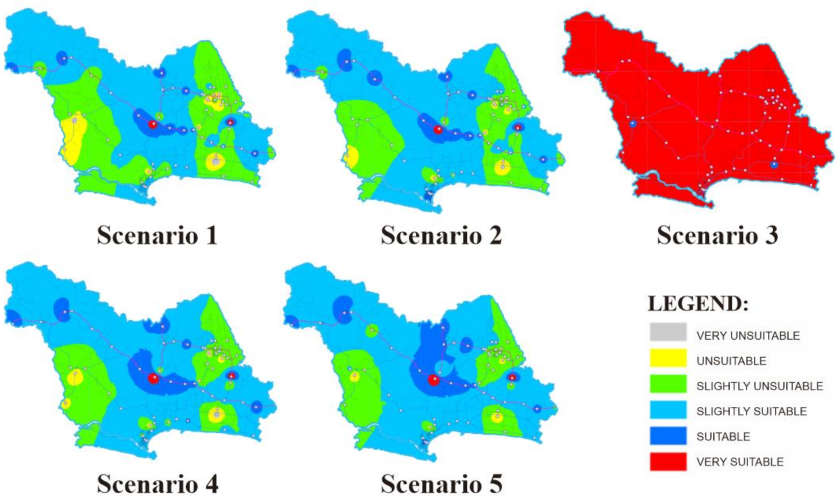

Figure 6. Suitability Maps of Scenarios

As per the result in table 8. The scenario shows that GS05 and GS22 are also the only two locations that achieve very suitable criteria in all improvement scenarios which indicates that these gas stations meet the recommended gas station criteria. The analysis results are visualized with GIS

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Euclidean distance command, the figure 6 shows the suitability map of each scenario illustrating the distribution of site suitability against the criteria defined in 6.

These results from table 8 also show that the improvement of sub-criteria land area, manpower availability, and supporting facilities don't change the number of gas stations that reach the very suitable level. This can be affected by how well each sub-criteria are met, as shown in table 9.

Table 9 – Result of Alternative Weight

Criteria	Existing Condition			Suitability Scenario Improvement		
	Average Score	Weight of Criteria	Existing Weight	Improvement Score	Improvement Weight	Different Weight
C.2.1	4.47	0.109	0.097	5	0.109	0.016
C.2.2	1.50	0.323	0.097	5	0.323	0.225
C.2.3	2.46	0.029	0.014	5	0.029	0.014
C.2.4	3.60	0.072	0.052	5	0.072	0.020

3.7. Optimization Analysis

At this stage, an optimization analysis will be carried out on the results of the suitability analysis. figure 6 distributes and visualizes the data based on the results of the suitability analysis in table 9. We will discuss the optimal analysis based on the results of the most promising gas stations under the current conditions.

The objective function Z can be calculated using mathematical equations based on the Maximum Coverage Location Problem (MCLP) in (5) to (9) to find out the most user destination points (POIs) that a potential gas station x can serve, which meets the best conditions for EVCS development. With the current existing conditions, according to the recommended locations, the maximum that can be covered by all locations is 79%, where the remaining 21% is outside the 5 km coverage of the EVCS location. In addition, 32% of the coverage is already within the existing EVCS boundary.

Table 10 – Performance of Optimalization Analysis

Data	Performance of Optimal Analysis Coverage				
	1	2	3	4	5
Number of POI (n)	1.201	1.201	1.201	1.201	1.201
Radius of coverage (r)	5km	5km	5km	5km	5km
Very Suitable Location (x)	2	2	40	2	2
Maximum POI in Coverage (Z)	68	68	560	68	68
Coverage of Gas Station (Z in %)	6%	6%	47%	6%	6%
Out of Coverage POI	21%	21%	21%	21%	21%
Existing EVCS Coverage	32%	32%	32%	32%	32%
Total Coverage Demand	38%	38%	79%	38%	38%

From table 10, we know the initial condition n, which is the total number of POI is 1201 units. It is known that the value of x in according to table 8 which meet the very suitable level gas station location, where scenarios 1,2,4,5 obtained a value of x = 2 and scenario 3 has a value of x = 59, unfortunately 19 recommended locations are in the constraint area so that 40 selected locations are analyzed. At 5 km from the potential gas stations, the value of i can be analyzed.

In all scenarios, GS05 and GS22 have an average POI coverage of 34 units/location, which is greater than the existing EVCS coverage of only 14 units/location. However, in terms of coverage, the two locations only cover 6%, which is still not optimal compared to the results of scenario 3, which was able to increase coverage from 6% to 47%. Comparrison of analysis output has been visualized in figure 6.

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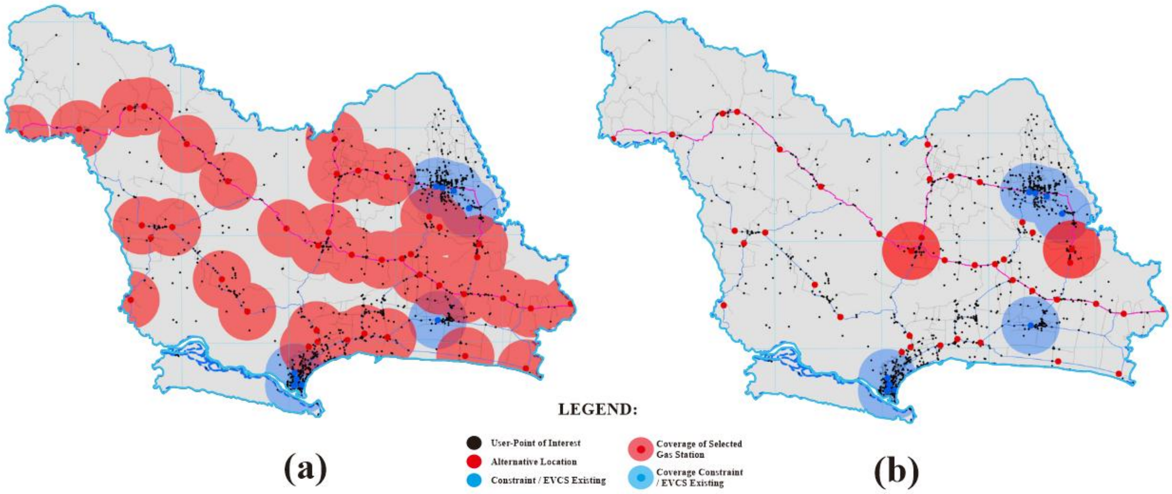

Figure 6. Visualization of User-Demand Coverage of (a) Suitability Scenario 3 and (b) others Suitability Scenarios

Figure 6 illustrates the coverage of alternative locations for EVCS development at gas stations, sub-figure (a) indicates that optimal conditions can be achieved when alternative locations have a suitability level of very suitable achieved through scenario 3 which increases coverage from 6% to 47%, while sub-figure (b) indicates that scenarios 1,2,4,5 have not been able to achieve optimal conditions. This indicates that the improvement scenario 3, namely the improvement of power network facilities, is the most optimal scenario in the EVCS development strategy.

4. DISCUSSIONS

The study revealed that a spatial multi-criteria analysis framework integrates GIS, AHP, and SAW methods can be effectively used to determine the location of EVCS development at gas stations. Based on the results of the analysis, the location of the gas stations proved to have a good fit with the technical requirements needed to meet the EVCS facility standards. This finding provides a significant contribution to the field of informatics, especially in the development of a spatial-based decision support system framework that can be replicated and integrated into an intelligent infrastructure planning platform. By utilizing geographic information system technology and multicriteria weighting methods, this approach produces an adaptive decision-making model based on spatial data, which is relevant in the context of urban digital transformation and the development of intelligent transportation systems.

The results of table 6, it was found that technical Factor (C.2) is more important than the Sustainability Factors (C.1), with a weight of C.1 and C.2 of 0.46638 and 0.53362. This shows that technical considerations, such as the availability of power networks, is more decisive in selecting an EVCS location than just the sustainability aspect. This aligns with the prior research about the importance of technical considerations in siting EVCS developments which will accelerate the EVCS development process at that location by utilising existing infrastructure [17], [19], [20], [24], [30], [41], [46]. This study emphasizes that effective decision-making requires integration between the two approaches, without sacrificing the principle of sustainability.

The results of the study also show consistency of findings with previous studies. In Table 10, this research uses gas stations as development locations where alternatif GS05 and GS22 have an average 34 POIs per location, which is greater than the existing EVCS coverage of only 14 POIs where existing EVCS are placed in offices and malls. This finding strengthens the results of the study which states that gas stations have a wider service coverage than other alternative locations [31]. Therefore, the results of this study support the policy recommendation to accelerate EVCS development by prioritizing gas stations as development locations, in line with the priorities stated in the EVCS Infrastructure Standard [22].

In this study, the results of the most optimal development strategy for EVCS at gas stations were obtained. Table 10 indicates that the focus on developing power network facilities can improve the achievement of gas stations against the specified criteria. In scenario 3, improvements to power network facilities, such as an increase in the main power supply and minimum backup to 88 kVA, increased the number of service stations to 59 locations, or 93% of the total number of service stations. The main and backup power supplies are important for maximizing charging speed because they enable the use of EVCS ultra-fast charging facilities and increase the potential for parallel charging for more than one vehicle. This finding is a novelty that has implications for the strategy of accelerating the development of EVCS which offers valuable insights for investor decision-making, which is in line with the other studies indicate that fulfilling technical and infrastructure requirements significantly influences the cost-effectiveness of investments in infrastructure for EVCS development [26]. A development strategy that focuses on the power network can be the best strategy for reducing cost, time, and investment optimization that can be used for gas station optimization in the selection of suitable locations for EVCS development.

The main contribution of this study is providing quantitative evidence that the development of EVCS at gas stations with power network facility improvement is an optimal strategy in terms of demand coverage, technical efficiency, and regulatory compliance. The proposed model can be adopted by policy makers, infrastructure developers, and technology providers to support data-driven planning systems in smart city development as to accelerate the availability of EV Infrastructure and have an impact on increasing EV adoption and reducing emissions.

However, this study has several limitations. First, the geographical scope is limited to a specific study area that has specific infrastructure characteristics and POI distribution. Therefore, validation of the model in areas with different infrastructure profiles is needed to test the generalizability of the approach. Second, the investment and operational cost aspects have not been analyzed in depth in this study, although these factors are very crucial in evaluating the feasibility of the project. Third, the operational safety aspect at gas stations as EVCS locations has not been the focus, even though it is an important issue that has not been widely discussed in previous literature [46].

Further research is suggested to expand the scope of the analysis by including investment cost parameters, long-term demand projections, and operational safety and security risk assessments. This study can also be further developed with the integration of more sophisticated spatial computing technologies such as machine learning for spatial optimization, in order to improve the accuracy and scalability of the developed model.

5. CONCLUSION

This study examines the optimization strategy of gas stations as EVCS development. The analysis shows that the integration of sustainability and technical approaches significantly improves the feasibility of the infrastructure and supports the fulfillment of technical standards for EVCS development. This finding shows that facility availability has a 1.14 times greater influence on demand coverage than proximity to user destinations. The empirical study identified GS05 and GS22 as the most potential locations in all scenarios. In addition, the power network criteria proved to have a strategic role. The results of suitability and optimization analysis indicated that upgrading the power network facilities was able to increase the number of highly suitable gas stations from 2 to 59 locations, as well

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as increase the coverage of user demand from 6% to 47%. This strategy was identified as the most optimal approach for EVCS development in gas stations.

The results prove that the combination of GIS-AHP-SAW integrated with optimization analysis (MCLP) can provide a comprehensive strategy for EVCS development at gas stations. This framework can contribute to the development of a spatial optimization framework based on geospatial data and infrastructure analysis, which contributes to strengthening the foundation of geographic information systems and the application of computer technology in supporting smart city planning, particularly in the electric vehicle ecosystem.

This study has limitations on geographical coverage, which may affect the generalizability of the results. Therefore, further research is recommended to test the model in different regions and ensure with applicable regulations. In addition, further research needs to examine aspects of investment cost, implementation time efficiency, and operational safety analysis is needed to ensure that this EVCS development strategy is feasible to be carried out at gas stations.

REFERENCES

[1] F. Alanazi, "Electric Vehicles: Benefits, Challenges, and Potential Solutions for Widespread Adaptation," Applied Sciences, vol. 13, no. 10, May 2023, doi: 10.3390/app13106016.

[2] D. R. Peters, J. L. Schnell, P. L. Kinney, V. Naik, and D. E. Horton, "Public Health and Climate Benefits and Trade-Offs of U.S. Vehicle Electrification," Geohealth, vol. 4, no. 10, Oct. 2020, doi: 10.1029/2020GH000275.

[3] R. Zaino, V. Ahmed, A. M. Alhammadi, and M. Alghoush, "Electric Vehicle Adoption: A Comprehensive Systematic Review of Technological, Environmental, Organizational and Policy Impacts," World Electric Vehicle Journal, vol. 15, no. 8, Aug. 2024, doi: 10.3390/wevj15080375.

[4] C. Tolliver, A. R. Keeley, and S. Managi, "Policy targets behind green bonds for renewable energy: Do climate commitments matter?," Technol Forecast Soc Change, vol. 157, Aug. 2020, doi: 10.1016/j.techfore.2020.120051.

[5] P. Fragkos et al., "Coupling national and global models to explore policy impacts of NDCs," Energy Policy, vol. 118, pp. 462–473, Jul. 2018, doi: 10.1016/j.enpol.2018.04.002.

[6] IESR, "Indonesia Electric Vehicle Outlook 2023," Jakarta: Institute for Essential Services Reform (IESR), 2023.

[7] Republic of Indonesia, Presidential Regulation No. 79 of 2023 on the Acceleration of the Battery Electric Vehicle Program for Road Transportation. Indonesia: "Ministry of State Secretariat of the Republic of Indonesia, 2023, pp. 1–5.

[8] Infogatrik, "Road to GGTC ITS," Buletin Ditjen Ketenagakelistrikan, vol. XX, pp. 1–60, 2024.

[9] J. Steenhuis, "Electric Vehicle Charging Stations in Hawaii," in 2023 Portland International Conference on Management of Engineering and Technology (PICMET), Monterrey, Mexico: IEEE Explore, 2023. doi: 10.23919/PICMET59654.2023.10216806.

[10] S. Paul Sathiyan et al., "Comprehensive Assessment of Electric Vehicle Development, Deployment, and Policy Initiatives to Reduce GHG Emissions: Opportunities and Challenges," IEEE Access, vol. 10, pp. 53614–53639, 2022, doi: 10.1109/ACCESS.2022.3175585.

[11] G. Santos and H. Davies, "Incentives for quick penetration of electric vehicles in five European countries: Perceptions from experts and stakeholders," Transp Res Part A Policy Pract, vol. 137, pp. 326–342, Jul. 2020, doi: 10.1016/j.tra.2018.10.034.

[12] I. Ullah, K. Liu, S. B. Layeb, A. Severino, and A. Jamal, "Optimal Deployment of Electric Vehicles' Fast-Charging Stations," J Adv Transp, vol. 2023, 2023, doi: 10.1155/2023/6103796.

[13] B. Yun, D. Sun, Y. Zhang, S. Deng, and J. Xiong, "A charging location choice model for plug-in hybrid electric vehicle users," Sustainability, vol. 11, no. 20, Oct. 2019, doi: 10.3390/su11205761.

[14] X. Chen, Z. Li, H. Dong, Z. Hu, and C. Chris Mi, "Enabling Extreme Fast Charging Technology for Electric Vehicles," IEEE Transactions on Intelligent Transportation Systems, vol. 22, no. 1, pp. 466–470, Jan. 2021, doi: 10.1109/TITS.2020.3045241.

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https://jutif.if.unsoed.ac.id
DOI: https://doi.org/10.52436/1.jutif.2025.6.6.4744

[15] N. Deb, R. Singh, R. R. Brooks, K. Bai, F. Barrero, and M. H. Kao, "A Review of Extremely Fast Charging Stations for Electric Vehicles," Energies (Basel), vol. 14, p. 7566, 2021, doi: 10.3390/en.

[16] Y. Zhang, J. C. Kim, H. W. Song, and S. Lee, "Recent achievements toward the development of Ni-based layered oxide cathodes for fast-charging Li-ion batteries," Nanoscale, vol. 15, no. 9, pp. 4195–4218, Jan. 2023, doi: 10.1039/d2nr05701h.

[17] M. Erbaş, M. Kabak, E. Özceylan, and C. Çetinkaya, "Optimal siting of electric vehicle charging stations: A GIS-based fuzzy Multi-Criteria Decision Analysis," Energy, vol. 163, pp. 1017–1031, Nov. 2018, doi: 10.1016/j.energy.2018.08.140.

[18] A. Mazza et al., "Categorization of Attributes and Features for the Location of Electric Vehicle Charging Stations," Energies (Basel), vol. 17, no. 16, Aug. 2024, doi: 10.3390/en17163920.

[19] F. Haces-Fernandez, "Risk Assessment Framework for Electric Vehicle Charging Station Development in the United States as an Ancillary Service," Energies (Basel), vol. 16, no. 24, Dec. 2023, doi: 10.3390/en16248035.

[20] R. Pagany, A. Marquardt, and R. Zink, "Electric charging demand location Model-A userand destination-based locating approach for electric vehicle charging stations," Sustainability, vol. 11, no. 8, Apr. 2019, doi: 10.3390/su11082301.

[21] United Stated, Department of Transportation, and Federal Highway Administration, "National Electric Vehicle Infrastructure Standards and Requirements," in 23 CFR Part 680, vol. 88, Federal Highway Administration (FHWA), Ed., Washington, DC, United Stated of America: Code of Federal Regulations, 2023, ch. 39, pp. 1–34. [Online]. Available: https://nca2018.globalchange.gov/chapter/12/

[22] M. of E. and M. R. Republic of Indonesia, Regulation of the Minister of Energy and Mineral Resources No. 1 of 2023 on the Provision of Electric Charging Infrastructure for Battery Electric Vehicles. BPK RI, 2023, pp. 1–48.

[23] M. Schmidt, P. Zmuda-trzebiatowski, M. Kiciński, P. Sawicki, and K. Lasak, "Multiple-criteria-based electric vehicle charging infrastructure design problem," Energies (Basel), vol. 14, no. 11, Jun. 2021, doi: 10.3390/en14113214.

[24] J. peng Liu, T. xi Zhang, J. Zhu, and T. nan Ma, "Allocation optimization of electric vehicle charging station (EVCS) considering with charging satisfaction and distributed renewables integration," Energy, vol. 164, pp. 560–574, Dec. 2018, doi: 10.1016/j.energy.2018.09.028.

[25] X. Wang, W. Xia, L. Yao, and X. Zhao, "Improved Bayesian Best-Worst Networks With Geographic Information System for Electric Vehicle Charging Station Selection," IEEE Access, vol. 12, pp. 758–771, 2024, doi: 10.1109/ACCESS.2023.3347037.

[26] K. Olcay and N. Cetinkaya, "Cost Analysis of Electric Vehicle Charging Stations and Estimation of Payback Periods with Artificial Neural Networks," in CIEES 2023 - IEEE International Conference on Communications, Information, Electronic and Energy Systems, Institute of Electrical and Electronics Engineers Inc., 2023. doi: 10.1109/CIEES58940.2023.10378772.

[27] F. Alanazi, M. Bilal, A. Armghan, and M. R. Hussan, "A Metaheuristic Approach Based Feasibility Assessment and Design of Solar, Wind, and Grid Powered Charging of Electric Vehicles," IEEE Access, vol. 12, pp. 82599–82621, 2024, doi: 10.1109/ACCESS.2024.3411291.

[28] D. Guler and T. Yomralioglu, "Suitable location selection for the electric vehicle fast charging station with AHP and fuzzy AHP methods using GIS," Ann GIS, vol. 26, no. 2, pp. 169–189, Apr. 2020, doi: 10.1080/19475683.2020.1737226.

[29] L. Sun, "Site selection for EVCSs by GIS-based AHP method," in E3S Web of Conferences, EDP Sciences, Oct. 2020. doi: 10.1051/e3sconf/202019405051.

[30] B. H. Lee, S. J. Jung, J. H. Sung, O. kyu Kwon, and B. S. Kim, "Selection of charging sites for electric vehicles in the Republic of Korea based on fuzzy analytic hierarchy process," Journal of the Korean Physical Society, vol. 79, no. 3, pp. 217–229, Aug. 2021, doi: 10.1007/s40042-021-00128-9.

[31] U. Zafar, I. S. Bayram, and S. Bayhan, "A GIS-based Optimal Facility Location Framework for Fast Electric Vehicle Charging Stations," in IEEE International Symposium on Industrial Electronics, Institute of Electrical and Electronics Engineers Inc., Jun. 2021. doi: 10.1109/ISIE45552.2021.9576448.

Vol. 6, No. 6, December 2025, Page. 5401-5417
https://jutif.if.unsoed.ac.id
DOI: https://doi.org/10.52436/1.jutif.2025.6.6.4744

[32] A. Sisman, "Identification of suitable sites for electric vehicle charging stations; a geographical information systems based multi criteria decision making approach," Energy Sources, Part A: Recovery, Utilization and Environmental Effects, vol. 45, no. 2, pp. 4017–4030, 2023, doi: 10.1080/15567036.2023.2200740.

[33] C. Van Westen, M. Damen, and W. Feringa, Training Package on National Scale Multi-Hazard Risk Assessment Theory Book National Scale Multi-Hazard Risk Assessment. 2013. Accessed: May 07, 2025. [Online]. Available: https://research.utwente.nl/en/publications/training-package-on-national-scale-multi-hazard-risk-assessment-t

[34] J. Zhou, Y. Wu, C. Wu, F. He, B. Zhang, and F. Liu, "A geographical information system based multi-criteria decision-making approach for location analysis and evaluation of urban photovoltaic charging station: A case study in Beijing," Energy Convers Manag, vol. 205, Feb. 2020, doi: 10.1016/j.enconman.2019.112340.

[35] N. K. Y. Suartini, D. G. H. Divayana, and L. J. E. Dewi, "Comparison Analysis of AHP-SAW, AHP-WP, AHP-TOPSIS Methods in Private Tutor Selection," International Journal of Modern Education and Computer Science, vol. 15, no. 1, pp. 28–45, Feb. 2023, doi: 10.5815/ijmecs.2023.01.03.

[36] F. Aydin and B. Gümüş, "Comparative analysis of multi-criteria decision making methods for the assessment of optimal SVC location," Bulletin of the Polish Academy of Sciences: Technical Sciences, vol. 70, no. 2, 2022, doi: 10.24425/bpasts.2022.140555.

[37] N. Kumar, T. Singh, J. S. Grewal, A. Patnaik, and G. Fekete, "A novel hybrid AHP-SAW approach for optimal selection of natural fiber reinforced non-asbestos organic brake friction composites," Mater Res Express, vol. 6, no. 6, Mar. 2019, doi: 10.1088/2053-1591/ab0b2b.

[38] A. J. Chabuk, N. Al-Ansari, H. M. Hussain, S. Knutsson, and R. Pusch, "GIS-based assessment of combined AHP and SAW methods for selecting suitable sites for landfill in Al-Musayiab Qadhaa, Babylon, Iraq," Environ Earth Sci, vol. 76, no. 5, Mar. 2017, doi: 10.1007/s12665-017-6524-x.

[39] J. Feng, S. X. Xu, and M. Li, "A novel multi-criteria decision-making method for selecting the site of an electric-vehicle charging station from a sustainable perspective," Sustain Cities Soc, vol. 65, Feb. 2021, doi: 10.1016/j.scs.2020.102623.

[40] Y. Ju, D. Ju, E. D. R. Santibanez Gonzalez, M. Giannakis, and A. Wang, "Study of site selection of electric vehicle charging station based on extended GRP method under picture fuzzy environment," Comput Ind Eng, vol. 135, pp. 1271–1285, Sep. 2019, doi: 10.1016/j.cie.2018.07.048.

[41] J. Priefer and L. Steiger, "Designing a GIS-AHP-Based Spatial Decision Support System for Discovering and Visualizing Suitable Locations for Electric Vehicle Charging Stations," in Wirtschaftsinformatik 2022 Proceedings, AIS Electronic Library, 2022, p. 31. [Online]. Available: https://aisel.aisnet.org/wi2022

[42] T. L. Saaty, "The Analytic Hierarchy and Analytic Network Processes for the Measurement of Intangible Criteria and for Decision-Making," in Multiple Criteria Decision Analysis: State of the Art Surveys, S. Greco, M. Ehrgott, and J. R. Figueira, Eds., New York, NY: Springer New York, 2016, pp. 363–419. doi: 10.1007/978-1-4939-3094-4_10.

[43] R. W. Saaty, "The Analytic Hierarchy Process-What it is and How it is Used," Pergamon Journals Ltd, vol. 9, no. 3–5, pp. 161–176, 1987, doi: doi.org/10.1016/0270-0255(87)90473-8.

[44] G. Demir, P. Chatterjee, and D. Pamucar, "Sensitivity analysis in multi-criteria decision making: A state-of-the-art research perspective using bibliometric analysis," Expert Syst Appl, vol. 237, Mar. 2024, doi: 10.1016/j.eswa.2023.121660.

[45] BPS, "Land Transportation Statistics," BPS-Statistics Indonesia, Jakarta, 2024.

[46] B. Wang, P. Dehghanian, S. Wang, and M. Mitolo, "Electrical Safety Considerations in Large-Scale Electric Vehicle Charging Stations," IEEE Trans Ind Appl, vol. 55, no. 6, pp. 6603–6612, Nov. 2019, doi: 10.1109/TIA.2019.2936474.